(12) UK Patent Application (19) GB (11) 2 222 696 (13) A

(43) Date of A publication 14.03.1990

(21) Application No 8816421.5

(22) Date of filing 09.07.1988

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(51) INT CL[4]
G03H 1/04

(52) UK CL (Edition J)
G2J J33B1

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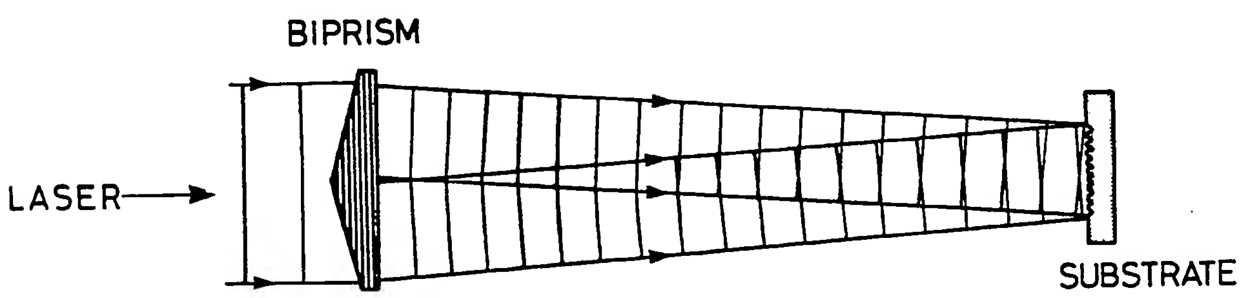
(58) Field of search
UK CL (Edition J) G2J JBSX1 J33A J33BX J33B1
INT CL[4] G02B, G03H
Online database; WPI

(54) **Holographic diffraction gratings**

(57) An optical device consisting of a single Fresnel biprism made of fused silica is placed in the output beam from a coherent excimer laser to overlap the two halves of the beam onto a material to produce a fine linear grating structure in one or more laser shots.



The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1982.

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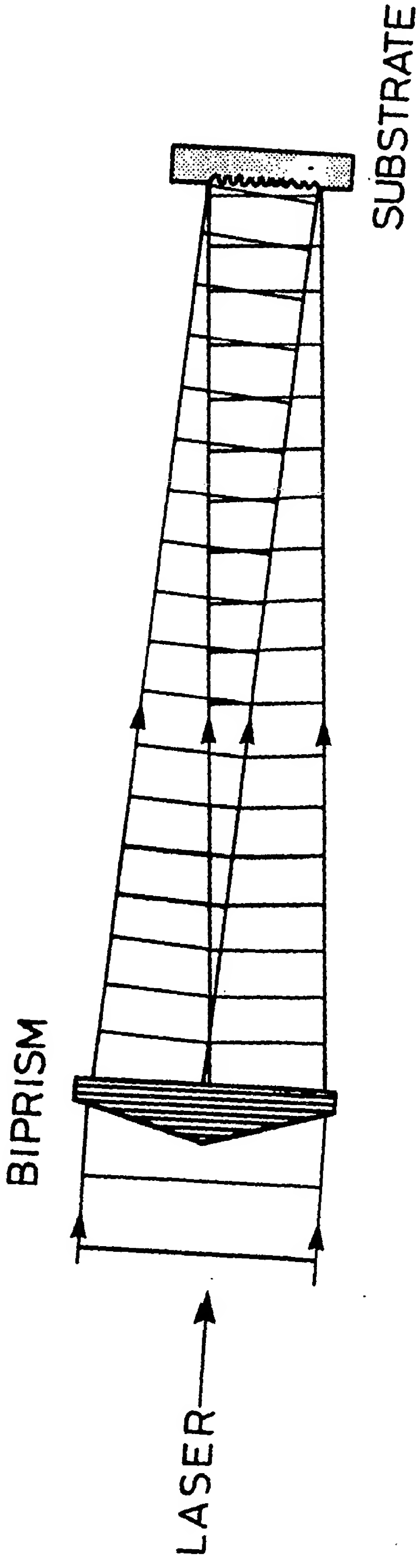

Fig 1

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The use of Fresnel biprism to fabricate holographic diffraction gratings using excimer laser radiation

This invention relates to the production of holographic gratings in materials using a pulsed excimer laser source and a Fresnel biprism to divide the wavefront of the laser output.

By exposure in a photosensitive material such as a photoresist, it is well known that the interference pattern created by combining two mutually coherent laser beams can be used to produce holographic grating structures[1]. Furthermore, it has been shown[2,3] that by using a high-powered pulsed UV KrF excimer laser source and a beamsplitter to divide the amplitude of the output beam into two, at the position of the recombination of the two beams exposure of a photoresist such as PMMA[2] or photoablation of the surface of some polymer materials such as PET (polyethylene terephthalate)[3] can be used to fabricate both transmission and reflection diffraction gratings on the surface of the substrate.

This invention claims that compared to the use of a beamsplitter, a Fresnel biprism can be more simply and conveniently used with pulsed excimer laser sources for the production of holographic gratings. Such a biprism, which divides the wavefront rather than the amplitude of the laser beam (as is the case when using the beamsplitter), can be used inline with the laser output as shown in Fig 1. Furthermore when used with wide (≥ 10mm) aperture laser beams such as those produced by commercially available excimer lasers, no further expansion of the laser beam is necessary and the biprism can be simply placed in front of the laser output.

The advantages of using the biprism to make holographic gratings by wavefront division of excimer laser beams are:

(a) The system is inline and can simply be placed in front of the output laser beam.

(b) Unlike amplitude division techniques, no external matching of optical path lengths of the interfering beams is required. This matching is automatically achieved by the accurate fabrication of th appropriate biprism. Accurate fabrication and alignment of the biprism demands less stringent requirements on the temporal coherence (linewidth) properties

of the laser. This is important when using rare gas halide lasers which normally produce emission over a wide spectral bandwidth (60-100 cm^{-1}) and so are relatively temporally incoherent. Since the biprism overlaps one half of the beam with the other the main requirement upon the incident laser beam is that it be spatially coherent.

(c) For a given incident laser beam, the spatially averaged laser energy density delivered to the substrate will be at least a factor of two higher than when using amplitude division techniques. This could be important when fabricating holographic gratings using material exposure techniques such as photoablative etching or photoinduced surface photo-refraction, which exhibit a pronounced exposure energy density threshold.

For substrate materials which can be exposed with a single short (10-50nsec) pulse from an excimer laser with the technique described in this invention, gratings can be made simply 'on the fly' with moving substrates. Gratings with an area of several square centimetres can be produced at rates exceeding 100 gratings/sec. The use of curved substrates allows concave or convex diffraction gratings to be fabricated by this simple method. Multiple 'crossed' Moiré fringe gratings can be produced by multiple exposures of the substrate at different orientations.

The first example which embodies the ideas described in this invention would be to place a Fresnel biprism fabricated from a suitable UV transmissive material such as fused silica into the output beam of a spatially coherent KrF 249nm excimer laser beam. By placing polymeric substrates such as polycarbonate, polyethylene terephthalate and polyimide at the position of full overlap of the two halves of the beam as produced by the biprism, holographic gratings are etched on the surface of the substrate by the process of UV laser ablative photodecomposition of the plastic material. If the polymer is transparent to diffracted light then the sinusoidal structures so produced may be used directly as transmission gratings. Alternatively subsequent deposition of a thin metallic reflective coating such as silver or aluminium can be used to fabricate reflective gratings.

The second specific example which embodies the ideas described in this invention would be to use the Fresnel biprism with a KrF excimer laser source

to fabricate surface photorefractive gratings in nonlinear optical materials such as $LiNbO_3$. It is known[4] that a photorefractive active layer can be induced on the surface of the $LiNbO_3$ crystals when they are exposed to radiation from a pulsed KrF laser which exceeds a well defined single pulse energy threshold of $\sim 50 mJ/cm^2$. Surface photorefractive gratings fabricated on $LiNbO_3$ using the Fresnel biprism in the manner described in this invention may be a useful fabrication technique for producing optical couplers in integrated optical devices.

This invention applies equally well to the production of holographic grating structures when using other excimer laser sources and exposure mechanisms to those mentioned.

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CLAIMS

1) An optical device consisting of a single biprism made of fused silica placed in the beam from a coherent excimer laser to divide the beam into two halves which are subsequently overlapped onto a material surface to generate a fine linear grating structure with one or more laser pulses.

2) Production of fine grating structures on moving polymer materials using the device of Claim(1) by the action of a single laser pulse.

3) Production of grating structures on plastic surfaces that are susequently curved by the use of the device of Claim (1).

4) Production of grating structures having varying line spacing on polymeric materials by the use of the device of Claim (1) to irradiate curved plastic surfaces.

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